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Volume 7 October, 1921 *Number 10*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

DIESEL ENGINES
Part II. Two Cycle Type, Solid Injection Type, etc.
Lubrication

Acidity in Oils

PUBLISHED MONTHLY BY
THE TEXAS COMPANY
PETROLEUM AND ITS PRODUCTS

An Advertisement for TEXACO URSA OIL

This is hard to write

Not because there is too little to say but because they gave me only this space to write it in

And they cautioned me to avoid superlatives, so I'll try my best and I'll make it snappy!

★ ★ ☆ ★ ★

OVER IN THE Submarine Base, with the first of the Fleet to come over, I got acquainted with TEXACO URSA OIL. And I'll say we were lucky from the start.

I've seen TEXACO URSA OIL used on every one of our Subs at this Base, on the French boats and on the captured German "U-boats".

So I know URSA.

First let me ask "have you ever seen a sample of Ursa."

If you have, you know how CLEAN it looks. And it is as clean as it looks.

And I think that this is thoroughly proven by the way it acts in the cylinders. I've opened up enough of them and found hardly enough carbon to talk about.

Once we got a batch of some other oil (name deleted by censor).

We were S. O. L. with carbon.

It meant lay-up.

No sleep for the black gang.

Take down engines.

Scrape carbon.

Put in new rings.

And then a solemn vow at midnight to STEAL Ursa if anything else was issued to us.

And the "gobs" that worked the centrifuges told me that they always knew when they had a batch of Ursa to run through. They said it came out clean and bright in short order. They said that the Ursa seemed to drop the water and sludge and you could hardly tell a "purified" lot from some that was drawn from an original barrel—the purified oil came out so clean.

And once in a while we get some fuel oil that had a pretty high per cent of sulphur. C'est la guerre! We had to use it. With URSA there was no thickening up of the oil. When we used another oil we got all kinds of emulsions which could not be broken up.

And I'll tell any operator of a Diesel that he will save himself hours and hours of time in scraping and cleaning rings, if he'll insist on TEXACO URSA OIL.

URSA

THE TEXAS COMPANY

Petroleum Products

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Diesel Engines

Part II. Two Cycle, Solid Injection etc.

LUBRICATION

[*EDITOR'S NOTE: In the September issue of LUBRICATION we considered a general analysis of Diesel Engines and discussed in detail the Four-Cycle Air Injection type, and the lubrication of the air compressor. In this issue we will consider other types of Diesel Engines, and the lubrication of the main engine.*]

THE handicap of the high initial cost of Diesel engines is of sufficient importance to warrant a careful study of possible developments by which it may be reduced in the future. Market prices today indicate a rough figure of almost $100 per horse-power for a Diesel engine against barely $40 per horse-power for a steam engine and its boilers. It is interesting to note at this point that one of our best commercial aviation engines, the "Liberty", costs less than $15 per horse-power in spite of its superfine materials and workmanship. Of course such an engine is overhauled almost every 100 hours, while a marine engine is expected to plug along for 6,000 hours or so before such an overhaul. One large manufacturer, however, recommends overhauling stationary engines after every 2,000 hours service.

MEANS OF REDUCING DIESEL COST

Among the possible developments by which the initial cost per horse-power of Diesel engines may be reduced in the near future are the following:

(A) Higher power per cubic foot of piston displacement may come into favor just as it has in the case of automobile and airplane engines. Even though this might require more frequent overhauls, unless better engineering makes this unnecessary, the overhauling cost of the smaller resulting engines will be lower, and it is possible that lower overall operating expenses will result.

(B) Any reduction of weight of a given size of engine by better distribution of stresses would be expected to bring a lower cost of the unit, since experience has shown that for a given class of workmanship all sizes of machinery cost about the same per pound of weight. The meaning is well illustrated by the recent developments of aviation engines, which are now lighter, much more durable as well as more reliable than only a few years ago.

(C) Another factor from which reduced costs should be expected is the two-cycle engine. Up to the present no pronounced difference in weight nor cost has been shown between the

two-cycle and the four-cycle engine, but the smaller sized cylinders for a given power, and the fewer valves and other small moving parts, should certainly result in less cost per horsepower for the two-cycle engine.

(D) Similar advantages to those of item C result from the use of double-acting cylinders.

(E) A development in which the object sought is not only a lower cost of the unit, but a simplification in making its successful operation more "fool-proof", is the elimination of the air compressor by using "solid" or "mechanical" injection of the fuel without air.

(F) Finally it must be realized that the greatest means of reducing initial costs, quantity production, is practically unknown today for Diesel engines, in the United States at least except for submarine work, and each engine produced here carries a heavy charge for experimental and development work.

All these elements working out their natural course, are sure to bring less costly engines in the future, which will in turn enormously increase the demand for them in the commercial world.

Items C, D and E are of sufficient importance and interest to warrant more detailed discussion.

C—Two-Cycle Diesel Engines

There is no theoretical difference between the four-cycle (previously described*) and the two-cycle method of developing power in an engine. The two-cycle is merely a mechanical modification by which the piston itself acts as an exhaust valve, and as soon as exhaust has occurred fresh air is blown into the cylinder from an outside source, the exhaust and suction strokes being thus eliminated. Hence but two strokes of the piston are necessary for a complete cycle, and in operation there are twice as many power strokes in a given number of revolutions, and twice as much power would be developed if each impulse were as great as for the corresponding four-cycle operation. Diagrammatically the operation of one form of two-cycle is shown in Fig. 18. An interesting modification of the same cycle by which the piston functions as the scavenging valves also, has been patented by Sulzer Frères of Switzerland, and is shown diagrammatically in Fig. 19. The patented feature is not in doing away with the exhaust and scavenging valves by means of cylinder ports uncovered by the piston, this is a feature of most two-cycle engines; it consists of delaying the *start* of scavenging until *after* exhaust has well started, and *stopping* it *after* exhaust is completed, by means of two sets of scavenging ports, one being controlled by a rotary valve, as shown. The conventional two-cycle engine does not use the upper set of scavenging ports nor the rotary valve.

* *Lubrication*, Sept., 1921.

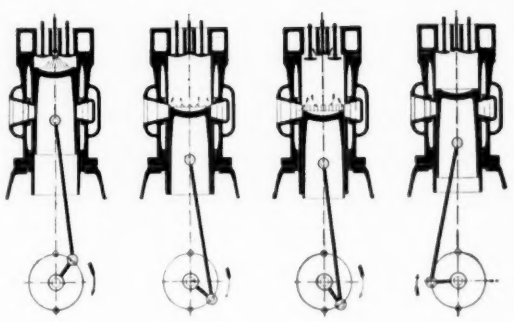


Fig. 18

Diagrammatic operation principles of the two-cycle Diesel Engine with scavenging valves

(A) Piston traveling down; all valves and ports closed; fuel injected and burnt during first part of stroke; gases expand.
(B) Piston traveling down; piston uncovers exhaust ports; burnt gases escape through exhaust ports, reducing the pressure to atmospheric.
(C) Piston traveling down; exhaust ports still uncovered; scavenging valves in head open; air under light pressure enters through scavenging valves and blows gases out of cylinder.
(D) Piston traveling up; piston covers exhaust ports; scavenging valves closed; air in cylinder is being compressed.

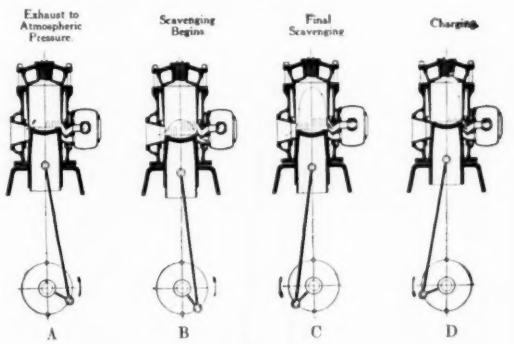
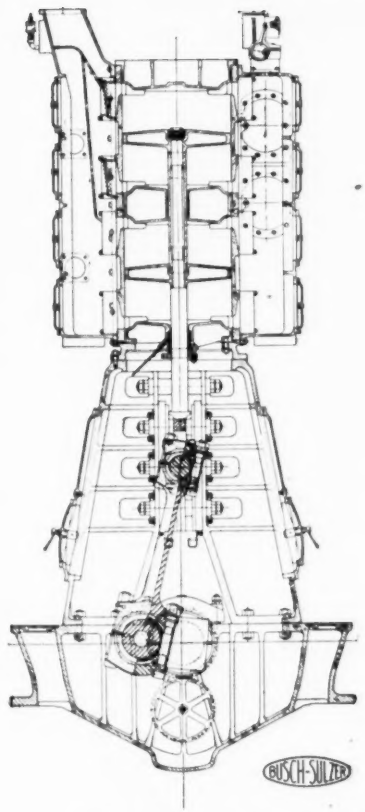


Fig. 19

Operating principles of the Sulzer two-cycle engine with two sets of scavenging ports, one set being controlled by a rotary valve

(A) Piston has uncovered upper scavenging ports, but rotary scavenging valve remains closed; piston is uncovering exhaust ports, burnt gases escape through exhaust ports, reducing the pressure to atmospheric.
(B) Piston is uncovering lower scavenging ports; rotary scavenging valve begins to open; air under light pressure enters from air duct, through lower scavenging ports and blows burnt gases out through exhaust ports.
(C) Piston has covered lower scavenging ports; exhaust ports remain partially uncovered; upper scavenging ports remain uncovered; scavenging valve remains open; scavenging is almost completed.
(D) Piston has covered exhaust ports; upper scavenging ports remain uncovered; scavenging valve remains open; cylinder is being charged with pure air at light pressure.



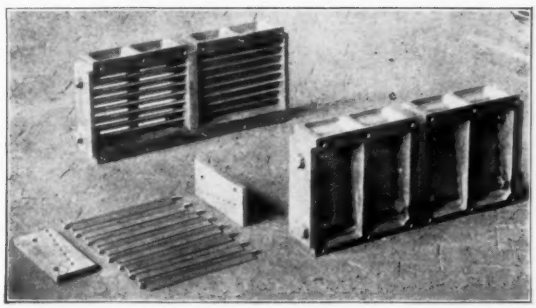
Courtesy of Busch-Sulzer Bros. Diesel Engine Co.

Fig. 20

Cross-section through a **double-acting scavenging pump** for two-cycle engines with two cylinders in tandem. The eight sets of automatic valves are shown, the two intake valves of the upper cylinder being in section.

All two-cycle engines require some external means of pumping all the scavenging air at a slight pressure ranging up to 5 or 7 pounds per square inch. Many means are taken to do this; the underside of the engine piston is used; or a larger piston is made integral with the engine piston; or as is most customary in present Diesel practice, an independent double-acting scavenging pump such as shown in Fig. 20 is driven at one end of the engine. It is almost the rule to find these pumps supplied with automatic valves of very light construction, like that of Fig. 21. An interesting modification of this scheme, which has great promise, especially for large units, is the use of a turbo-compressor driven by an electric motor.

A theoretical study of these two Diesel cycles promises the following prominent advantages for the two-cycle engine:



Courtesy of Busch-Sulzer Bros. Diesel Engine Co.

Fig. 21

Details of automatic valves used in the scavenging pump of Fig. 20

1. Almost twice as much power in a given size cylinder.

2. Elimination of exhaust-valves (and usually scavenging valves) in the cylinder-head, which makes this complicated unsymmetrical casting much less vulnerable to cracking from the stresses caused by expansion from large temperature changes, as may be understood from Fig. 22. Difficulties experienced in cooling large exhaust-valves to prevent warping and burning, and complicated head castings place a limit to the size of cylinders of four-cycle engines not found with two-cycle engines. A great deal of valve gear is eliminated by the absence of these valves, and accessibility to vital parts thus facilitated.

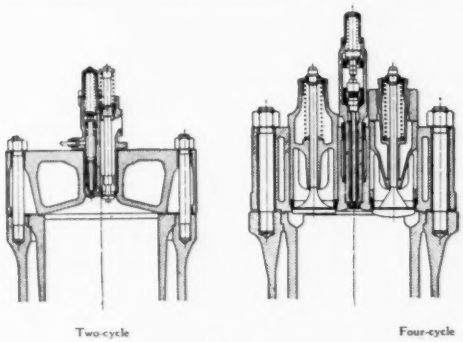


Fig. 22

Comparison of cylinder heads for a two-cycle Diesel (left) which carries only the fuel and starting-air valves, with a four-cycle engine (right) which carries exhaust and inlet valves in addition. The starting-air valve of the latter is not shown. Notice how much simpler is the cooling of the former.

3. Less weight and less cost per horsepower developed.

4. More even delivery of power, because of more power impulses in a given time.

5. The higher cylinder temperatures and lack of valves make it easier to operate on very viscous grades of fuel.

On the other hand there are the following disadvantages:

1. Scavenging is not as perfect, thus the power is not doubled but about 75% greater, and the fuel consumption per horse-power correspondingly higher.
2. The scavenging air pump is a large added mechanism, increasing weight and cost, and consuming about 10% of the engine power.
3. The greater work done in a cylinder subjects it to greater heat, and therefore to greater expansion stresses, and makes lubrication more difficult.
4. It is difficult to make a joint between the cylinder liner and jacket at the exhaust port which will not let water leak into the cylinder. If the water is salt, or if there is much sulphur in the fuel, such a leakage would be almost disastrous to lubrication, and hence to the life of the engine.
5. With scavenging ports on one side of a cylinder, and exhaust on the other, uneven expansion will cause stresses and possibly warping of the cylinder liner.
6. As the load on the connecting-rod bearings is always in one direction and never reversed by the piston momentum, as happens with four-cycle engines at the end of the exhaust stroke, bearing lubrication is much more difficult.

Actual experience so far has been more favorable to the four-cycle engine, though most engineers feel that the future, especially for large sizes, lies with the two-cycle engine, and that all its disadvantages can eventually be overcome. In this connection one must bear in mind that Sulzer Frères alone have built 450,000 horse-power of two-cycle engines simultaneously with the same amount of four-cycle engines. Possibly the failure of many two-cycle engines has been due to the fact that their apparently greater mechanical simplicity decoyed less experienced engineers who overlooked the details of real technical difficulty.

D—Double-Acting Engines

Another method for reducing the cost and weight per horse-power is to increase the power from each cylinder by making it double-acting, like almost all steam engines; that is, to provide a crosshead and pass the piston-rod through a stuffing-box as is done in Fig. 23, so that a power cycle can be gotten from each side of the piston. Such a construction is particularly promising for two-cycle engines because one set of exhaust ports can be used for both sides of the piston. On the other hand, piston cooling particularly, and cylinder lubrication, as well as the piston rod packing and its lubrication, are very difficult matters to handle. When they are finally mastered double-acting engines are certain to be a prominent type.

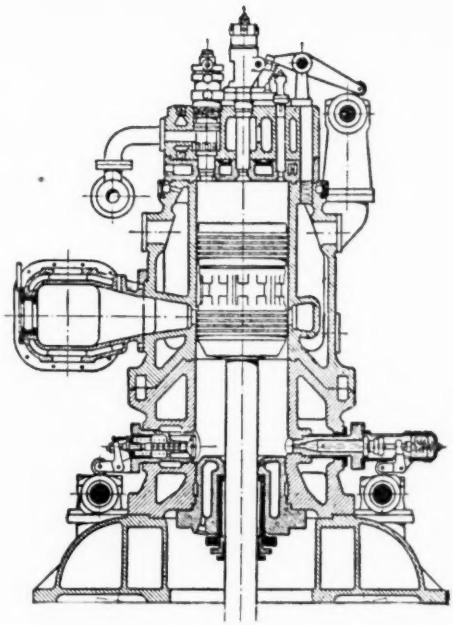


Fig. 23

Section of a **double-acting two-cycle cylinder** with common exhaust ports at the center for both ends. The stuffing box for the piston rod is, of course, water-cooled.

E—"Mechanical" or Airless Fuel Injection

In order to eliminate the cost, complication and even danger of the high pressure air system required by the first successful Diesel engines, a great deal of development has been under way for several years, toward injecting the liquid fuel without air. The advantages of such a simplification of design are particularly noticeable for very small engines where the use of air injection would be almost impossible because of cost and the lack of care given these units.

The "Semi-Diesel"

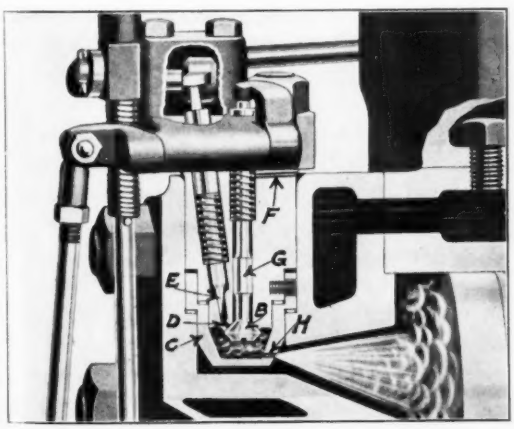
For several years a large number of small so-called "Semi-Diesel" engines have been marketed, in which the liquid fuel is injected onto a hot surface within the combustion chamber, which sprays, "cracks" and ignites the fuel.

These engines are more correctly termed "Surface Ignition" engines, because compression of the free air in the cylinder is not sufficient to supply the temperature required for ignition without the hot surface. Starting thus requires heating the surface as a preliminary step. After the engine has started, the temperature of the ignition surface is maintained by the heat of combustion, since water cooling is not used for this part and it naturally runs hot whether of the "hot-bulb", or "hot plate" type.

Aside from the nuisance of preliminary heating, the cracking of fuel results in the liberation of carbon, and the exhaust of semi-Diesel engines is apt to be smoky. There is also a pronounced tendency for the rapid accumulation of carbon because of the cracking.

The "Super-Diesel"

Another type of small engine in which, however, ignition is not secured by hot surfaces, is the Hvid engine sometimes spoken of as the "Super-Diesel". Many of these engines are in regular use on American farms, in units as small as 1½ horse-power. The fuel valve cage of this engine terminates in a small steel cup, as may be seen in Fig. 24, into which a mixture of air



Courtesy of "Mechanical Engineering"

Fig. 24

Section of part of a small Hvid engine cylinder showing details of the fuel cup and valve

(from passages F and G) and fuel (from metering pin E and orifice D) is drawn during the suction stroke of the piston. Near the end of the compression stroke the highly heated air which rushes into the cup through the holes H, volatilizes or cracks enough fuel to start combustion, which forces the rest of the oil out through the holes H, much as would an air spray. It is claimed that these engines can be started cold, and while they thus show points of superiority over the semi-Diesel they also lack flexibility as to speed. Both are apt to smoke and run erratically at low speeds. Note that exact control of the *time* of ignition and the rate of combustion is not possible.

The "Solid Injection" Diesel

The two methods just described, of handling fuel without air injection, may be looked upon as stepping-stones toward the elimination of air injection by forcing the oil directly into the cylinder at the time of combustion. It is a very difficult matter to do this in such a way that the exhaust will not smoke even at low speeds. Vickers, Ltd., of England, after building almost 500,000 horse-power of such engines for submarine and other uses, claims now to have eliminated smoke entirely, though the engines used during the War are reported to have smoked badly. In America particularly energetic development is under way among whom Worthington, Ingersoll-Rand and De La Vergne claim to have already accomplished the desired results. It seems certain that this is one of the surest and most promising Diesel developments held for the immediate future.

In general, two systems are used for solid injection; in one, oil is pumped to the fuel valves at a pressure of 4,000 to 5,000 pounds per square inch, and is admitted when the valve is opened by suitable cams. The quantity of fuel sprayed varies with the *time* the valve is open, and thus with both the cam profile and engine speed. The second system makes use of a separate plunger pump for each cylinder, which meters out the required quantity of fuel and delivers it at whatever pressure is necessary.

Fig. 25 shows a type of fuel valve used on some solid injection engines of the second type, with the spiral passages D used to secure a turbulent quickly spraying stream, and the heavily spring loaded check valve C, which prevents fuel remaining in the fuel line from "dribbling" in after the quantity desired has been forced through. It appears that the oil stream passing

through a spray valve continues like a straight needle for a little distance before it breaks up into the desired spray. This spray when once formed is so fine that it floats away when in the open like a cloud of smoke and can be easily ignited, though the solid needle can be ignited only with great difficulty.

Before leaving solid injection engines it is well to recall that the refrigerating action of expanding injection air is, of course, not present in these engines and as a consequence ignition can take place with lower compression pressures. The high pressure necessary for fine atomization may easily inject the fuel more rapidly than is normal for the constant pressure combustion of the theoretical Diesel engine. Indeed some engines have so rapid a pressure rise that their indicator cards look like those from high compression Otto rather than Diesel engines; though most solid injection engines are about mid-way between. Such a pressure rise is sometimes accompanied by the "pinking" or detonation sound familiar with kerosene carburetor engines, which has been severe enough with some semi-Diesel engines to require the injection of water. This, of course, greatly complicates lubricating requirements.

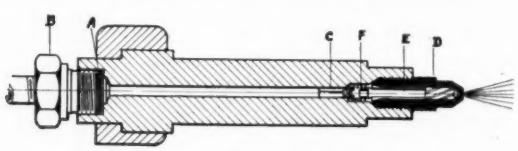


Fig. 25

A fuel valve used on one type of "solid-injection" Diesel engine, where a helical passage at the tip assists in breaking up the oil stream as it passes the nozzle, and a spring loaded check-valve prevents "dribbling".

REVERSING MARINE DIESEL ENGINES

All marine engines directly connected to their propeller shafts are "direct-reversing" except the small sizes where a clutch and reverse-gear are used for this purpose. In order to make a four-cycle engine "direct-reversible", that is, so that its own direction of rotation is reversible, an entirely different set of cams is usually provided for the intake, exhaust, fuel, and starting-air valves, one set being used for each direction of rotation. Ordinarily both sets of cams are side by side on the same cam-shaft. The operation of reversing consists of stopping, changing the cams, and then starting again by compressed air in the usual manner. Reversing from full speed in one direction to full speed in the other can be done in less than 20 seconds, and is as simple as reversing a steam engine.

It is an interesting study to observe how different designers carry out the details of the mechanism by which one set of cams is changed for the other. One very successful and much used scheme is shown in Fig. 26 in which the

Courtesy of Worthington Pump & Machinery Corp.

Fig. 26

Typical Reversing detail of engine in Fig. 16, showing how the cam rollers are withdrawn from the cams so that the cam-shaft can move the cams for reverse into position.

cam rollers are anchored to levers fulcrumed on a cranked lay-shaft. When this lay-shaft is rotated, it pulls the cam rollers outward and away from the cams. The cam-shaft is then slid along axially until the other set of cams is in place, and the rollers are then returned by a rotation of the lay-shaft to its original position. This whole series of operations is performed in the proper sequence from a single point. Another ingenious means of accomplishing the same end is shown in Fig. 27, where the valve rockers are fulcrumed on eccentrics. When the shaft carrying these eccentrics is rotated, the rollers are lifted from the cams, moved sideways because the eccentrics are mounted at a small angle, and upon further rotation of the shaft the rollers are lowered to the second set of cams. On medium-sized engines the rotation of a hand-wheel carries out these steps, and in larger engines an air cylinder is used instead, with an oil dash-pot to regulate the rate of movement.

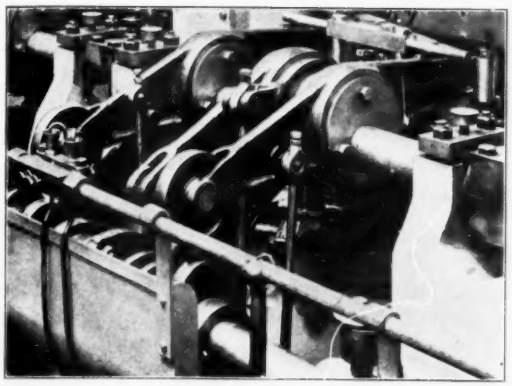
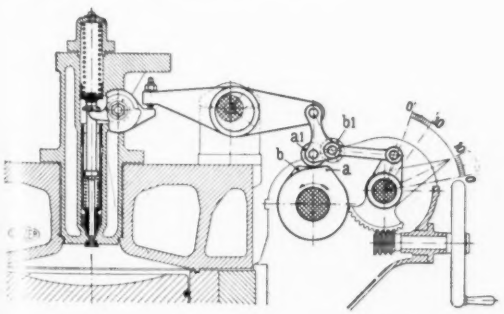


Fig. 27

Method used by Workspoor for moving valve rocker and roller for "ahead" cams to "astern" cams by turning a tilted eccentric fulcrum. Rockers are shown in an intermediate position with rollers raised.

Reversing a two-cycle engine is a simpler mechanical operation, since there are no intake or exhaust valves requiring different timing. Fig. 28 shows a very simple way of shifting the valve-rocker roller from one cam to the other for reverse operation. A triangular piece carries two rollers, one in the plane of each cam, and by moving it to and fro, one roller or the other will be engaged with its cam when the other is clear.

Another very interesting method which should be mentioned here, is that of reversing a four-cycle engine just as if it were a two-cycle engine, i.e., by changing the timing of the fuel and starting air valves, but not the intake and exhaust valves. Since this means that the intake valves for ahead operation become exhaust valves when running astern, and vice versa, an exhaust manifold is required for the intake as well as exhaust valves.



Courtesy of Sulzer Freres

Fig. 28

A simple means of changing from one set of cams to the other for reversing a two-cycle engine, without moving the cam shaft

LUBRICATION OF DIESEL ENGINES

The superiority of circulating force-feed lubrication to all crankshaft bearings is now so well appreciated that it is the rule rather than the exception. Nevertheless there are many old time operators who object to the enclosed crankcase construction always used with this lubricating system, because they cannot feel the bearings and know if they are running hot. They overlook the fact that most of the bearing troubles experienced in the past have been where wick or some other form of drip lubrication was used, and that bearing trouble is practically unknown with the pressure system if the clearances are correct, and if the oil flow is not interrupted. Of course there is a possibility that excessive clearance may develop in one bearing which will deprive the other bearings of their oil supply, but this can be detected by a drop in the oil pressure. On some engines oil is lead to the crankpins, and even the wrist-

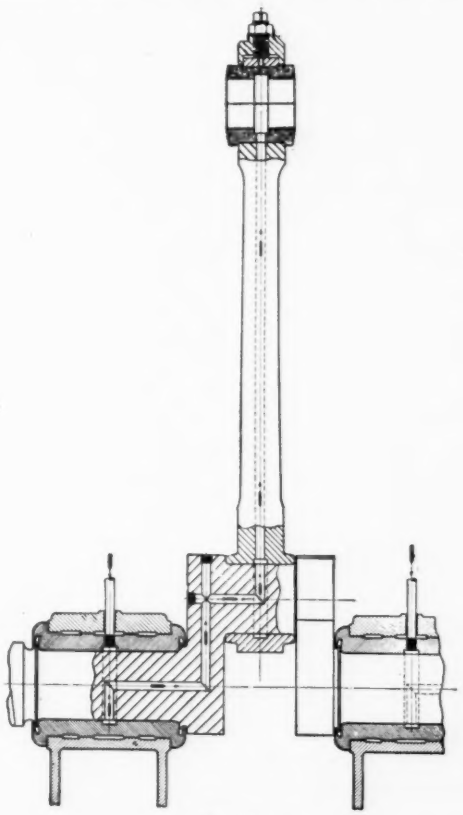
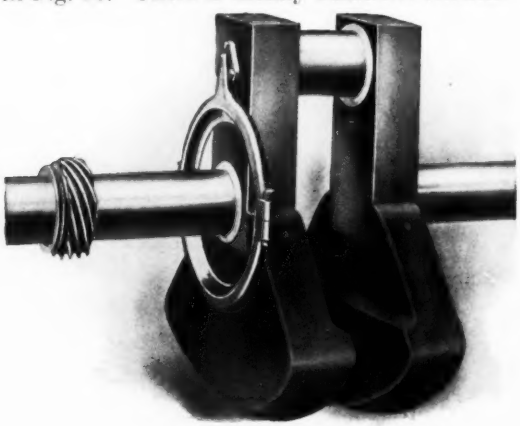


Fig. 29

Lubrication of crankshaft, crank-pin and wrist-pin **by the full pressure circulating system**, oil being supplied to the main bearings under a pressure of 10 to 30 pounds.

pins under pressure by means of passages drilled through the crankshaft from the main bearings to the crankpins (Fig. 29), as is done in airplane engines. It is more customary to lubricate the crankpins by collecting the oil leaking from the main bearings, into rings attached to the crank-cheek as shown in Fig. 30. There is usually sufficient centrifugal force to cause a positive flow of oil by this means to the crankpin, and if a check valve is placed in the oil lead carrying oil up the connecting rod to the wrist-pin, centrifugal force will feed the wrist-pin also under a moderate pressure.



Courtesy of De La Vergne Machinery Company
Fig. 30

Lubrication of crank-pins with oil caught from the ends of the main bearings by a ring on the crankshaft. Centrifugal force supplies the only oil pressure.

Since one of the characteristics of the pressure system is the circulation of much more oil than necessary for lubrication alone in order to cool the bearings somewhat, excess oil is thrown from the rotating parts and sprays around in such a way that a tightly enclosed crankcase is very desirable to prevent wastage of oil. Another and even more important reason for tightly enclosed crankcases is to keep dust and dirt from entering the lubricating system where they would form an abrasive and cause rapid bearing wear. As a precaution, filters are always used between the oil pump and bearings, preferably of the duplex type, which allows one to be cleaned at a time without interfering with the flow of oil. Screens should be used also between the crank-sump and the oil pump to strain out any foreign matter such as rags, etc., which would interfere with the pump action. Cotton waste should never be used about any engine with a circulating lubricating system because it is so easy for small pieces to get into the oiling system, but, unfortunately, this is common practice. A tank should always be placed in the system to allow very fine foreign matter to settle out, which otherwise would pass through the filters. Sometimes it is combined with the filter, or used as a reserve oil tank. At all events drains should be provided not only for drawing off the sediment, but also any water which has settled out. All possible means must be taken to prevent water, especially salt water, from entering or remaining in the lubricating oil.

The oil sprayed from the crank and crankshaft bearings is sufficient to reach the cylinders to a considerable extent in trunk-piston engines, and in some cases it has been found to be ample for the lubrication of the cylinders. In fact, it is difficult to prevent too much oil from reaching the cylinders. Instances are known where so much lubricating oil reached the combustion space that when the engine was overheated it ran without any fuel oil, merely by burning the lubricant. A similar instance was reported where a manufacturer had difficulty in meeting his fuel consumption guarantee until by increasing the pressure of the lubricating system, enough power was secured from the lubricating oil burned to pass the test. These extreme cases indicate why unusual precautions should be taken to get as little oil on the cylinder walls as possible. An excess can do no good except act as a very expensive fuel, and it is sure to gum up the piston rings. Accordingly splash guards are often used to deflect oil spray from the cylinders, while some designers resort to the expedient of the cross-head piston type shown previously in Fig. 16.*

When such precautions are taken, it is usual to lubricate the cylinders with measured quantities of new oil supplied by mechanical force feed oilers, which deliver oil to two or more points equidistant around the cylinder, at such a height as to cover the top piston-ring when the piston is at the bottom of its stroke. The plungers of the lubricators are so timed as to deliver a few drops of oil just at the end of the power stroke, there being at least one pump plunger and oil lead to each cylinder, as shown

* See *Lubrication*, Sept., 1921.

in Fig. 32. The oil used by such lubricators is supplied only once and then only in the smallest quantity that will do the required work.

In the usual type of engine, partly burned oil and fuel work past the piston and contaminate the crankcase oil, not only with carbon particles but fine particles of iron worn from the cylinders, ash from the fuel, and water. It will be observed that there are usually two distinct lubricating systems to Diesel engines, one for the bearings where the oil is used over and over again, and where a cooler is sometimes needed to prevent the oil from getting too hot, and the other for the cylinders, where the oil is used only once. There are also a large number of small parts about the valve gear which must be oiled with a squirt can or grease cups. One well known six cylinder engine has 180 parts that must be lubricated this way. Valve stems are often left with no better provision for lubrication than this, and it is necessary with many engines for an operator to squirt a mixture of oil and kerosene on the valve stems, the kerosene being used to thin down any oil which has thickened from exposure to the heat of the exhaust valve stem. It is excellent practice to use some sort of guard or flange on the exhaust valve stem to deflect the gases from contact with the oil film on the stem when the valve opens, as shown in Fig. 17 (left)* and Fig. 31. If this is done it is possible to lubricate the stem by a mechanical lubricator without fear that the oil will gum from the heat and interfere with the operation of the valve. Notice the gland at the upper end of the stem guide of Fig. 17 (left)* which is used to prevent the exhaust gases from blowing the lubricant out of the space between the stem and guide.

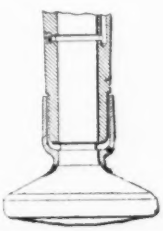


Fig. 31

A **shroud on an exhaust valve** to protect the lubricating oil on the valve stem from the heat of the exhaust gases. Use of this device greatly reduces the tendency of such a valve to stick.

* See *Lubrication*, Sept., 1921.

REQUIREMENTS OF LUBRICATING OIL

For practical reasons it is desirable to use the same oil for all parts of an engine—cylinders and bearings. But little need be said about the type of oil to be used, in spite of all the elaborate specifications that have so frequently been published. It is assumed, of course, that no operator would be so "penny-wise and pound foolish" as to jeopardize the life of an engine costing nearly $100 per horse-power, by using an oil not known to be well refined and of the first quality. Unfortunately, the degree of refining cannot well be judged by those who operate the engines, and they must accordingly rely on the reputation of the refiner for this. In addition, bear in mind that:

1. The oil must, of course, not congeal at any temperature to which it will be exposed in service.
2. The oil must be viscous enough to form a fair piston seal, but not so viscous as to cause undue fluid friction in the bearings.
3. It must spread readily over the cylinder walls, and not remain in streaks or patches.
4. It must not form bad emulsions as it is frequently mixed inadvertently with a little water in service, sometimes even salt-water.
5. When exposed to the intense heat of combustion, which will decompose any oil, it must leave a minimum of carbon when disintegrated, and the carbon must not be gummy.
6. It must not be so volatile that an undue quantity will be necessary to maintain a good film on the cylinder walls.
7. It must not react and thicken with sulphur from the fuel.

Several of these items are conflicting. For example, the conditions in a two-cycle engine are particularly bad for cylinder lubrication, because the oil is not only more frequently subjected to heat, but the velocity of the burned gases at the exhaust ports greatly increases the evaporation of oil from this part of the cylinder. A less volatile oil can be secured only at the expense of higher "carbon residue" and higher "cold test". The choice of the best oil to use is thus, as in other branches of engineering, a compromise in which the judgment of the specialist must be resorted to as to which particular items enumerated above must be given the greatest weight.

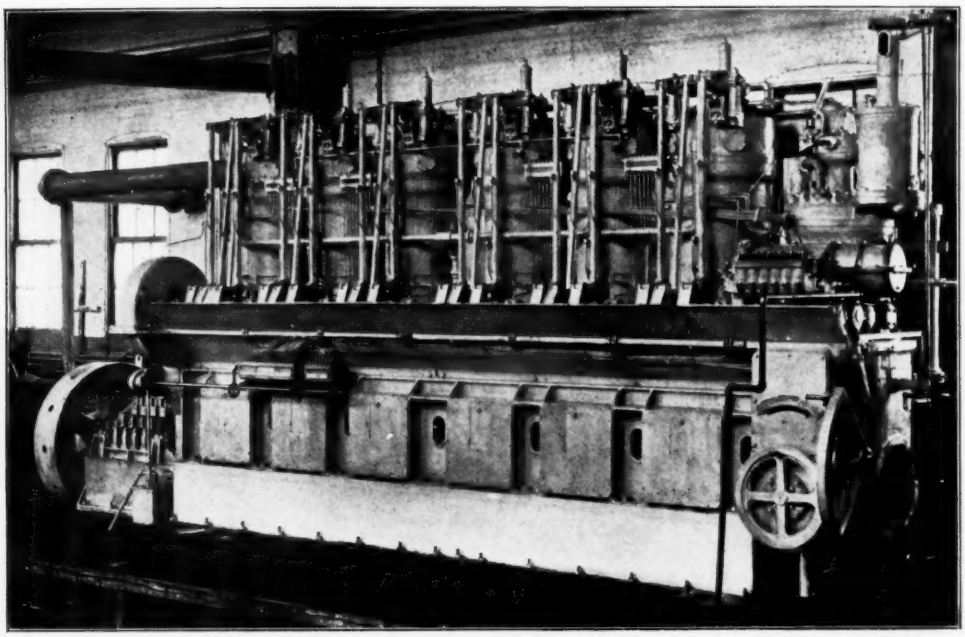


Fig. 32

A 500 Shaft Horse Power McIntosh & Seymour Marine Engine, showing near the left center the mechanical lubricator, with its drive and oil lines, which supply measured quantities of fresh oil to cylinders. Between the cylinders are shown the gravity feed oil sights and lines of the circulating oil system to all main and similar bearings. The air compressor is just back of the fuel pump, at the right, from which the fuel lines can be seen leading to each spray valve. At the bottom right is the hand wheel by which reversing is accomplished, and just right of it is the throttle which operates the starting air at the bottom of its stroke, and the upper part of its sector controls the quantity of fuel supplied to each spray valve.

COOLING WATER

When sea water is used as cooling water it must not be allowed to run over 110° F. because of the precipitation of salt at higher temperatures, though 140° F. would otherwise be a better temperature for the engine. It is very important when an engine is stopped that a vigorous circulation of the cooling water be maintained for some time afterward, to cool off the hot metal parts. Otherwise there may be enough local heating of the water to precipitate salt at points where it is most important that there shall be no interference with cooling. Cracked cylinders also may result. An even more important advantage is secured by this rapid cooling on account of the fact that prolonged exposure of a film of oil on a hot cylinder wall while the engine is idle, will cause it to evaporate, and when a new start is made it may be with dry cylinders.

If there is any possibility of an engine being exposed to freezing temperature when shut down, it is imperative that all jacket water be drained, or cracked castings are almost sure to result.

SUMMARY

It has seemed expedient to deal with the Diesel engine at length because of the strong position promised for it in the near future by present economic conditions, as was outlined in the first part of the article appearing in the September issue of *Lubrication*. Accordingly, the general constructional features of the type of Diesel best known because of being well tried out and proved in previous service, were given. This was followed by a description of alternative constructions now in the development stage, which promise to hold the field during the next few years. With a knowledge of the construction and function of the various parts of Diesel engines it was logical to follow briefly with the general methods and requirements of lubrication common to these engines, for as is well known, the success or failure of many an engine is tied up with the perfection of its lubricating system. The failures of many engines in the past have been due to the designer's inability to handle lubrication properly. Certain it is that no engine will give prolonged service unless it is correctly lubricated.

Acidity in Oils

ACIDITY, to the ordinary man, who has forgotten his early school training, is a condition in a material which gives it a sour taste, as, for example, ancient milk has considerable acidity, also ancient butter, and, likewise, too, ancient cider. The taste is due to products which have developed by reason of bacterial action and which the chemist speaks of as acids. Without going into the technical definition of an acid, we may, for practical purposes, consider it to be a chemical compound—gas, liquid or solid—which will combine with an alkali such as caustic soda in a particular manner. This combination results in a disappearance of acidic properties of the acid and the alkaline properties of the lye, and the formation of a neutral substance.

Acids, generally, are divided into two classes, designated as "inorganic" and "organic", the organic acids being those containing the element carbon and derived from organic sources. Among the best known inorganic acids are sulfuric acid (or oil of vitriol), nitric acid (or aqua fortis) and hydrochloric (or muriatic) acid. Among the better known organic acids are lactic acid, occurring in passe milk; butyric acid, occurring in butter in a similar state; acetic acid, the main constituent of vinegar, which should by rights come from fermentation of hard cider but does not always, and oleic acid, which occurs, to a greater or less extent, in practically all vegetable or animal oils.

In addition there are certain acids to be found in petroleum oils which are called "naphthenic" acids. These are so weak in their action that they cause no corrosion of metal and in general are of interest only in explaining why certain petroleum oils have the power to partly neutralize caustic soda when brought in contact with them.

Of the inorganic acids the only one of interest, when considering petroleum lubricants, is sulfuric acid which is used in the refining of lubricating oils to remove objectional impurities, and from which, of course, lubricating oil must be entirely freed before its use. While in the earlier days of the petroleum industry it occasionally happened that traces of sulfuric acid were found in lubricating oil, at the present time, this is a condition which is practically non-existent due to improved methods of refining. The erroneous idea that there is a possibility of the presence of sulfuric acid is still unfortunately perpetuated in the public mind by the clause generally used in specifications for petroleum lubricants, that they "must be free from mineral acid."

Oleic acid is of importance in cases where petroleum oils are compounded with animal or vegetable oils. It is desirable that the content of fatty acid be particularly low where mixtures of petroleum and animal or vegetable oils are used for burning and illuminating purposes. The amount is also usually limited in specifications for lubricants of a compounded nature. The purpose of this limitation is primarily to furnish an assurance that the lubricant has been compounded from first class and reasonably pure ingredients and is not an indication per se of the value of the lubricant. On the other hand, in products such as cutting oil a considerable percentage of acid is not only not deleterious but may be advantageous. As already indicated, however, in straight mineral lubricating oils we often find an apparently acidic condition which can only be explained as being due to the somewhat mysterious naphthenic acids. The presence of these acids in an oil is in no wise an indication of its inferiority as a lubricant and in fact some investigators have claimed such presence an advantage. This point is still subject to a more complete study.

As will be shown, acidity is determined by bringing a sample of the oil in question in contact with a definite quantity of alkali, such as caustic potash, and determining the amount of caustic potash which is neutralized by the acid present. This may be reported as the percentage, by weight, of the caustic potash required to neutralize a sample of the oil, and when so reported, is known as the acid number, the acid number of an oil being the amount, in milligrams, of caustic potash required to neu-

tralize one gram of oil. This, however, is but little used in the petroleum industry.

When the determination of acidity was first made on petroleum oils, the investigator was looking for sulfuric acid and, consequently, when any acid was found it was reported in terms of sulfur tri-oxid (sulfur tri-oxid plus water gives sulfuric acid). However, as refining methods improved, and sulfuric acid disappeared as a constituent of lubricating oils, it became customary to report any acidity that was found to be present as a percentage of oleic acid. Oleic acid has not at all the same composition as any of the naphthenic acids which have so far been isolated, but the advantage of reporting acidity as percentage of oleic acid lies in the fact that the investigator is able to form, an approximate picture in his mind of the amount of organic acid present.

The use of these terms, as might be anticipated, has often resulted in confusion in the lay mind. A laboratory report showing a percentage of sulfuric acid naturally leads one to believe that sulfuric acid is actually present; while a report showing the presence of oleic acid—an acid which does not occur in petroleum—when reported on a straight mineral oil, raises suspicion as to contamination of petroleum oil with an animal or vegetable oil. It should, however, be borne in mind that the use of both of these terms is for convenience only and not to indicate actual presence of either of these acids.

In order to standardize the methods of determining acidity and eliminate any variation which might arise due to different methods of carrying on a test, the American Society of Testing Materials has after considerable study adopted the following method of determining free acid:

Test for Free Acid in Lubricants

Serial Designation D 47-18

Accurately weigh 10 g. of the oil into a flask, add 50 cc. of 95 per cent alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein, alkali blue or tumeric as an indicator, agitating thoroughly after each addition of alkali.

Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 g. of fat or oil).

Follow the same method for mineral oils excepting the alcohol which should consist of equal proportions of distilled water and 95 per cent alcohol.

In titrating dark-colored mineral oils, the end reaction is better observed when alkali blue 6 B. is used as the indicator.

One cc. of tenth-normal alkali equals 0.0282 gram of oleic acid. Alkali, 1 cc. of which is equivalent to 0.00996 g. of KOH, and 1 cc. of which is equivalent to 0.5 per cent of oleic acid, may be used.

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